What is claimed is:

1. A method for improving the physical and mechanical properties of ion-conducting materials, comprising:

providing an ion conducting base material;

providing a crosslinking agent; and

incorporating the crosslinking agent into the ion-conducting base material through hydroxyl and sulfonic acid condensation or though amine and sulfonic acid condensation.

2. A method as in claim 1, wherein the incorporation takes place in a non-aqueous environment.

3. A method as in claim 1, wherein the crosslinking agent has a chain that includes an aromatic polymer chain, an aliphatic polymer chain, an organic or inorganic polymer network, or any combination thereof.

4. A method as in claim 1, wherein, in addition to one or more of amine, hydroxyl, or sulfonic acid groups, the crosslinking agent has at least one functional group to form a covalent crosslinking bond with the ion conducting base material.

5. A method as in claim 1, wherein the ion conducting base material is an organically-based material, an inorganically-based material, or a composition thereof.

6. A method as in claim 1, wherein the ion conducting base material is organically based and containing aromatic or aliphatic structure.

7. A method as in claim 6, wherein the aromatic structure includes poly-aryl ether ketones and poly-aryl sulfones.

8. A method as in claim 6, wherein the aliphatic structure includes perflourinated or styrene co-polymer types

9. A method as in claim 1, wherein the ion conducting base material contains one or more inorganic additives.

10. A method as in claim 9, wherein the inorganic additive is selected from the group consisting of clay, zeolite, hydrous oxide, and inorganic salt.

11. A method as in claim 10, wherein the clay includes an aluminosilicate-based exchange material selected from the group consisting of montmorillonite, kaolinite, vermiculite, smectite, hectorite, mica, bentonite, nontronite, beidellite, volkonskoite, saponite, magadite, kenyaite, zeolite, alumina, rutile.

12. A method as in claim 1, wherein the ion conducting base material has a given molecular weight and/or polymer structures with functional groups that include sulfonic acids, phosphoric acids, carboxylic acids, imidazoles, amines, and amides.

13. A method as in claim 1, wherein the crosslinking agent is hydroxyl terminated and the ion conducting base material is sulfonated, and wherein the incorporation includes direct covalent crosslinking between the hydroxyl terminated crosslinking agent and the sulfonated ion-conducting base material such that their reaction is in the form of

$$HO\text{-}R_1\text{-}OH + 2(HSO_3)\text{-}R_2 \rightarrow R_2\text{-}SO_2\text{-}O\text{-}R_1\text{-}O\text{-}SO_{2\text{-}}R_2 + 2H_2O$$

where R_1 is the hydroxyl terminated crosslinking agent's main chain and R_2 is the sulfonated ion conducting base material.

14. A method as in claim 13, wherein the main chain includes one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.

15. A method as in claim 13, wherein the sulfonated ion conducting base material includes, one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.

16. A method as in claim 1, wherein the crosslinking agent is amine terminated and the ion conducting base material is sulfonated, and wherein the incorporation includes direct covalent crosslinking between the amine terminated crosslinking agent and the sulfonated ion-conducting base material such that their reaction is in the form of

$$H_2N\text{-}R_1\text{-}N\text{-}H_2 + 2(HSO_3)\text{-}R_2 \rightarrow R_2\text{-}SO_2\text{-}NH\text{-}R_1\text{-}NH\text{-}SO_{2.}R_2 + 2H_2O$$

where R_1 is the amine terminated crosslinking agent's main chain and R_2 is the sulfonated ion conducting base material.

17. A method as in claim 1, wherein the crosslinking agent is sulfonic acid terminated and the ion conducting base material is amine or hydroxyl terminated, and wherein the incorporation includes direct covalent crosslinking between the sulfonic acid terminated crosslinking agent and the amine or hydroxyl terminated base ion-conducting material such that their reaction is in the respective form of

$$HO_3S\ \text{-}R_3\text{-}\ SO_3H + 2(HO)\text{-}R_4 \rightarrow R_4\text{-}SO_2\text{-}O\text{-}R_3\text{-}O\text{-}SO_{2.}R_4 + 2H_2O$$

or

$$HO_3S\ \text{-}R_3\text{-}\ SO_3H + 2(H_2N\ )\text{-}R_4 \rightarrow R_4\text{-}SO_2\text{-}NH\text{-}R_3\text{-}NH\text{-}SO_{2.}R_4 + 2H_2O$$

where R_3 is the sulfonic acid terminated crosslinking agent's main and R_4 is the amine or hydroxyl terminated ion conducting base.

18. A method as in claim 1, wherein incorporation involves a reaction solvent, including a high boiling point, non-polar solvent selected from a group consisting of dimethyl sulfoxide (DMSO), n-methyl pyrrolidinone (NMP), dimethyl acetamide (DMAC) and dimethylformamide (DMF).

19. A method as in claim 1, wherein incorporation proceeds under azeotrophic distillation via a removal of water by toluene to facilitate reaction kinetics.

20. A method as in claim 1, wherein incorporation involves 0.1% to 8% crosslinking agent's molar equivalents with respect to ion conducting base material's sulfonic acid sites.

21. A method as in claim 1, wherein incorporation involves 0.1% to 8% crosslinking agent's molar equivalents with respect to ion conducting base material's amine or hydroxyl group sites.

22. A method as in claim 1, wherein the ion conducting base material contains an inorganic cation exchange material.

23. A method as in claim 22, wherein the inorganic cation exchange material is selected from a group consisting of clay, zeolite, hydrous oxide, and inorganic salt.

24. A method as in claim 22, wherein the inorganic cation exchange material further includes a silica based material and a proton conducting polymer based material.

25. A method for adding functionality to ion-conducting materials, comprising

providing an ion conducting based material;

providing a modified crosslinking agent; and

incorporating the modified crosslinking agent into the ion-conducting base material through hydroxyl and sulfonic acid condensation or though amine and sulfonic acid condensation.

26. A fuel cell, comprising:

an anode;

a cathode

fuel supply to the anode;

oxidant supply to the cathode;

a polymer electrolyte membrane positioned between the cathode and anode and fashioned with crosslinking agent crosslinked into an ion-conducting base material through hydroxyl and sulfonic acid condensation or though amine and sulfonic acid condensation; and

a membrane electrode assembly (MEA) with the polymer electrolyte membrane.

27. A method of fabricating a polymer membrane suitable for use in an electrochemical fuel cell, comprising:

synthesizing a polymer material of viscous nature which contains

(a) crosslinked polymer chains,

(b) a solvent for dissolving the polymer chains, and

(c) any quantity of inorganic additives,

spreading the synthesized polymer material to form a uniform thickness layer on a substrate;

allowing the solvent to evaporate under controlled atmosphere from the synthesized polymer material to yield the polymer electrolyte membrane; and

preparing the polymer electrolyte membrane for use in a fuel cell by protonation and purification.

28. A material with tailorable microstructure, comprising:

ion conducting base material that is sulfonated; and

a crosslinking agent that is hydroxyl terminated and is crosslinked to the sulfonated ion conducting base material via direct covalent crosslinking characterized by

$$HO\text{-}R_1\text{-}OH + 2(HSO_3)\text{-}R_2 \rightarrow R_2\text{-}SO_2\text{-}O\text{-}R_1\text{-}O\text{-}SO_2.R_2 + 2H_2O$$

where R_1 is the hydroxyl terminated crosslinking agent's main chain and R_2 is the sulfonated ion conducting base material.

29. A material as in claim 28, wherein the ion conducting base material includes an inorganic cation exchange material

30. A material as in claim 29, wherein the inorganic cation exchange material is selected from a group consisting of clay, zeolite, hydrous oxide, and inorganic salt.

31. A material as in claim 29, wherein the inorganic cation exchange material further includes a silica based material and a proton conducting polymer based material.

32. A material as in claim 28, wherein the main chain includes one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.

33. A material as in claim 28, wherein the sulfonated ion conducting base material includes, one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.

34. A material with tailorable microstructure, comprising:

ion conducting base material that is sulfonated; and

a crosslinking agent that is amine terminated and is crosslinked to the sulfonated ion conducting base material via direct covalent crosslinking characterized by

$$H_2N\text{-}R_1\text{-}N\text{-}H_2 + 2(HSO_3)\text{-}R_2 \rightarrow R_2\text{-}SO_2\text{-}NH\text{-}R_1\text{-}NH\text{-}SO_{2\text{-}}R_2 + 2H_2O$$

where R_1 is the amine terminated crosslinking agent's main chain and R_2 is the sulfonated ion conducting base material.

35. A material as in claim 34, wherein the ion conducting base material includes an inorganic cation exchange material

36. A material as in claim 35, wherein the inorganic cation exchange material is selected from a group consisting of clay, zeolite, hydrous oxide, and inorganic salt.

37. A material as in claim 35, wherein the inorganic cation exchange material further includes a silica based material and a proton conducting polymer based material.

38. A material as in claim 34, wherein the main chain includes one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.

39. A material as in claim 34, wherein the sulfonated ion conducting base material includes, one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.

40. A material with tailorable microstructure, comprising:

ion conducting base material that is amine or hydroxyl terminated; and

a crosslinking agent that is sulfonic acid terminated and is crosslinked to the amine or hydroxyl terminated ion conducting base material via direct covalent crosslinking characterized by, respectively,

$$HO_3S\text{-}R_3\text{-}SO_3H + 2(HO)\text{-}R_4 \rightarrow R_4\text{-}SO_2\text{-}O\text{-}R_3\text{-}O\text{-}SO_2\text{-}R_4 + 2H_2O$$

or

$$HO_3S\text{-}R_3\text{-}SO_3H + 2(H_2N)\text{-}R_4 \rightarrow R_4\text{-}SO_2\text{-}NH\text{-}R_3\text{-}NH\text{-}SO_2\text{-}R_4 + 2H_2O$$

where R_3 is the sulfonic acid terminated crosslinking agent's main and R_4 is the amine or hydroxyl terminated ion conducting base.

41. A material as in claim 40, wherein the ion conducting base material includes an inorganic cation exchange material

42. A material as in claim 41, wherein the inorganic cation exchange material is selected from a group consisting of clay, zeolite, hydrous oxide, and inorganic salt.

43. A material as in claim 41, wherein the inorganic cation exchange material further includes a silica based material and a proton conducting polymer based material.

44. A material as in claim 40, wherein the main chain includes one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.

45. A material as in claim 40, wherein the sulfonated ion conducting base material includes, one or more chains selected from a group consisting of an aromatic polymer chain, an aliphatic polymer chain, organic molecules and inorganic molecules.